Surface Skin Temperature from Geostationary Satellite Data

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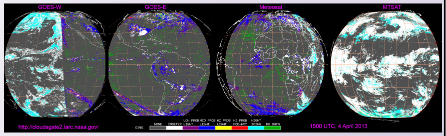
Introduction

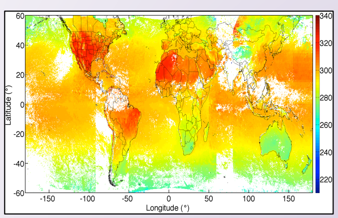
The temporal and spatial coverage of geostationary sensors enable frequent retrieval of near-global **surface skin temperature (T_s)**. In addition to cloud and other products (e.g., aircraft icing potential in figure below) developed from GEOsats around the globe, NASA Langley is producing estimates of T_s by applying an inverted correlated *k*-distribution method to clear-pixel values of **TOA infrared temperature (T)**. This method yields clear-sky T_s values that are within ±2.0 K of measurements from ground-site instruments, e.g., the US Climate Reference Network (USCRN) and Atmospheric Radiation Measurement (ARM) climate research facility infrared thermometers. Comparisons of the T_s product with MODIS land surface temperature reveal a relative accuracy within ±1 K for both day and night. These data, especially the eventual pixel-level data, will be useful for assimilation with atmospheric models, which rely on high-accuracy, high-resolution initial radiometric and surface conditions. Modelers should find the immediate availability and broad coverage of these T_s observations valuable, which can lead to improved forecasting for both regional and global numerical weather prediction models.



Near-global aircraft icing potential (none, indeterminable, low/medium/high probability for light icing, high probability for moderate to heavy icing, night icing, and no data) from geostationary satellites

Background and Methodology

- Near-global radiometric and cloud microphysical property retrievals are achieved through the use of five GEOsats
- Nominally 8 retrievals per day, with potential for 24
- Modern-Era Retrospective Analysis for Research and Applications (MERRA) model forecasts provide T_s and thermodynamic profiles used to compute the atmospheric transmissivity (via correlated *k*-distribution[1,2]); together yielding estimated near-surface to TOA layer temperatures
- CERES cloud mask compares observations with estimates of T or visible-channel reflectance
- Mean observed properties are computed for clear and cloudy pixels in each 1.0° × 1.0° grid box: the cloud mask is repeated using the new clear-sky values
- Clear T pixels are grouped into 0.3125° x 0.25° tiles and brought to the surface using a modified correlated *k*-distribution technique[1,2], thus yielding **surface-leaving brightness temperature (T_o)**
- Application of CERES emissivity (ε_s) maps yields the near-global **high-resolution skin temperature products (HRTP)**



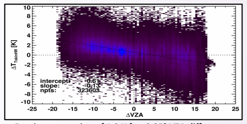
Near-Global, High-Resolution Surface Skin Temperature (K): Mean 18:00 UTC retrievals for July 2012

Inter-satellite boundaries reflect slight differences in cloud detection owing to a variety of reasons, such as pixel size. Nevertheless, discontinuities are small, but can be partially explained by spectral band differences

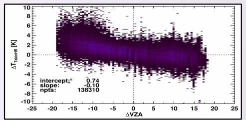
The gap region, between 50° and 90° east, filled by the Fengyun 2E (FY-2E) satellite remains questionable

High-Resolution Surface Temperature Compared with Ground-Site Measurements

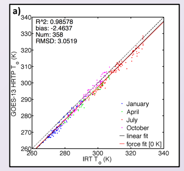
- HRTP T_o retrievals from GOES-13 allow for frequent comparison with data taken at the Southern Great Plains (SGP) ARM 11.0-µm upwelling Infrared Thermometer (IRT; T_o) and the Stillwater, OK and Avondale, PA USCRN Apogee Precision Infrared Thermocouple Sensors (IRTS-P; T_o)
- Because of a viewing zenith angle (VZA) dependency, must correct surface temperature to be warmer to match ground sites



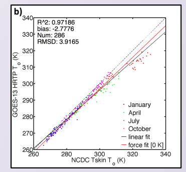
Daytime correction of 1.8 K for -9.25° VZA difference between GOES-East and GOES-West

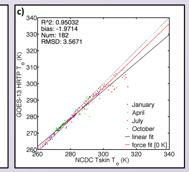


Nighttime correction of 1.7 K for -9.25° VZA difference between GOES-East and GOES-West



Comparisons of GOES-13 HRTP (T_o) values with measurements taken from the a) ARM 10-m upwelling IRT, the b) Stillwater, OK USCRN IRTS-P (T_o), and the c) Avondale, PA USCRN IRTS-P (T_o), on October 2011 and January, April, and July 2012. Data points are color-coded by month. VZA dependency correction has NOT been applied





	Mean Difference (K)				RMSD (K)			
	GOES – ARM (SGP)	GOES – USCRN (OK)	GOES – USCRN (PA)	GOES – MODIS	GOES – ARM (SGP)	GOES – USCRN (OK)	GOES – USCRN (PA)	GOES – MODIS
Day	-0.08	-1.35	-1.29	0.89	1.92	3.81	3.94	1.64
Night	-1.70	-0.51	0.95	-0.51	2.00	1.06	1.48	1.08
Both	-0.70	-0.98	-0.17	0.41	1.95	2.93	2.98	1.46

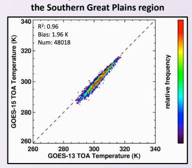
Mean differences and root mean square differences (RMSDs) between measured HRTP (T_o) and ARM IRT (T_o), HRTP (T_o) and USCRN IRTS-P (T_o), and HRTP (T_s) and MODIS Land Surface Temperature (T_s). Beta-version VZA dependency correction applied for ground site comparisons. Note: The ARM IRT saturation limit of 330 K diminishes the true daytime bias

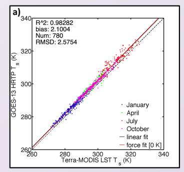
See panel below for more information on the MODIS comparison

High-Resolution Skin Temperature Compared to MODIS Land Surface Temperature

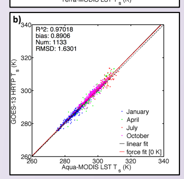
- MODIS Land Surface Temperature (LST; T_s) data averaged to same resolution as HRTP tiles and compared to spectrally corrected HRTP (T_s) values over two 15° × 10° regions for both day and night
- First region includes the SGP domain and second region is over the northeastern United States
- Disparity between HRTP and Terra-MODIS daytime LST could be due to different viewing and illumination geometry
- Average clear-sky T anisotropy for the GOES-13 viewing and illumination angles at MODIS overpasses in SGP region are 0.5 - 4.0 K
- Small differences can also, at least partially, be explained by atmospheric corrections

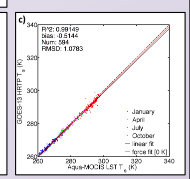
July 2012 comparison of GOES-15 and GOES-13 clear-sky top-of-atmosphere infrared temperature near 17:45 UTC in the Southern Great Plains region





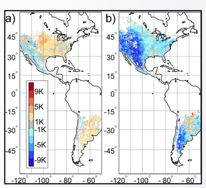
Clear-sky comparisons of HRTP (T_s) and MODIS LST (T_s) within 15 min of each other over the (a) Southern Great Plains at 17:45 UTC, (b) Northeast United States at 17:45 UTC and (c) Southern Great Plains at 08:45 UTC during October 2011 and January, April, and July 2012. Emissivity for both sensors comes from the MODIS Level-2 product, using Collection 5, 11.0-µm, 5-min granules



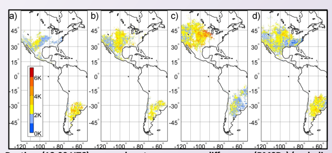


High-Resolution Skin Temperature Compared to GEOS-5 Land Surface Temperature

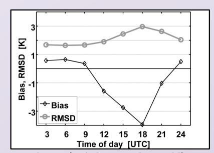
- Model comparisons utilize land surface temperature output from the NASA Goddard Earth Observing System Version 5.7.2 (GEOS-5) at the 0.3125° × 0. 25° resolution
- Differences between the GEOS-5 estimates and the GOES-13 satellite retrievals of skin temperature are not small



Mean difference (K) between GEOS-5 land surface temperature and GOES-13 HRTP for clear-sky conditions at (a) 06:00 UTC (nighttime) and (b) 18:00 UTC (daytime), averaged over 1 August 2011 to 31 July 2012



Daytime (18:00 UTC) seasonal root-mean-square differences (RMSDs) (excluding seasonal mean difference) in Kelvin between GEOS-5 land surface temperature and GOES-13 HRTP for clear-sky conditions for (a) Dec 2011–Feb 2012, (b) Mar–May 2012, (c) Aug 2011, Jun–Jul 2012, and (d) Sep–Nov 2011

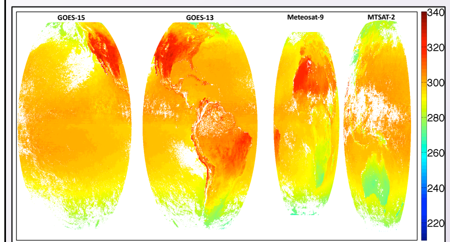


Bias and RMSD (excluding annual mean differences) in Kelvin between GEOS-5 land surface temperature and GOES-13 skin temperature for clear-sky conditions, averaged over 1 August 2011 to 31 July 2012, and areas in North, Central, and South America

- Analysis nevertheless suggests that HRTP values are largely consistent with the independent GEOS-5 estimates
- Spatial and temporal variations of the biases must be addressed as part of the assimilation system
- These issues can be fully resolved through improvements in the GEOS-5 atmospheric model; particularly the moist physics and cloud parameterizations[3]

Development Toward a Real-Time Pixel-Level Skin Temperature Product

- More continuous near-global coverage compared to the HRTP
- Cloudy/clear decision on pixel level greatly reduces chances of filtering good data points
- Close to 24 nearly-full disk retrievals for each satellite per day
- Instances of pixel misclassification remain, however, effect can be diminished by applying a buffer around known cloudy pixels

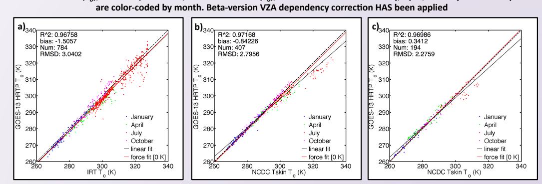


Near-global pixel-level surface skin temperature (K) for the GOES-West, GOES-East, Meteosat-9, and MTSAT-2 sub-satellite domains. FY-2E domain not shown

Uses mean of the 18:00 UTC retrievals for July 2012

Pixel used only when classified as clear and are not adjacent to any pixels classified either as cloudy or no/bad retrieval

Comparisons of GOES-13 pixel-level T_o values with measurements taken from the a) ARM 10-m upwelling IRT, the b) Stillwater, OK USCRN IRTS-P (T_o), and the c) Avondale, PA USCRN IRTS-P (T_o), on October 2011 and January, April, and July 2012. Data points are color-coded by month. Beta-version VZA dependency correction HAS been applied



	Mean Difference (K)			RMSD (K)		
	GOES – ARM (SGP)	GOES – USCRN (OK)	GOES – USCRN (PA)	GOES – ARM (SGP)	GOES – USCRN (OK)	GOES – USCRN (PA)
Day	-1.07	-1.56	-0.44	3.45	3.88	2.91
Night	-2.00	-0.18	1.01	2.5	1.08	1.53
Both	-1.51	-0.84	0.34	3.04	2.80	2.28

Mean differences and root mean square differences (RMSDs) between measured pixel-level T_o and ARM IRT (T_o), and pixel-level T_o and USCRN IRTS-P (T_o). Beta-version VZA dependency correction applied

Note: ARM IRT saturation limit of 330 K diminishes true daytime bias

Conclusions and Future Work

- Except for certain viewing & illumination conditions, results comparable to MODIS to ±1 K, but with the added benefits of having consistent geometry and higher sampling frequency for any one location
- These nearly instantaneous, near-global datasets are available for assimilation in numerical weather prediction models
- Important step taken towards assimilation into the GEOS-5 NWP system
- Need to better characterize angular and emissivity dependencies using nadir MODIS measurements
- Will employ the GMAO GEOS-5 Model at finer resolution for pixel-level product, and globally validate near-real-time, near-global pixel-level skin temperature product by end of 2013
- Need to broaden the scale of data assimilation from Americas to all non-polar regions

References

[1]Goody, R.; West, R.; Chen, L.; Crisp, D. The correlated-k method for radiation calculations in nonhomogeneous atmospheres. J. Quant. Spectrosc. Radiat. Transfer 1989, 42, 539–550.

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[3]Scarino, B.; Minnis, P.; Palikonda, R.; Reichle, R.H.; Morstad, D.; Yost, C.; Shan, B.; Liu, Q. Retrieving Clear-Sky Surface Skin Temperature for Numerical Weather Prediction Applications from Geostationary Satellite Data. Remote Sensing. 2013; 5(1):342-366.